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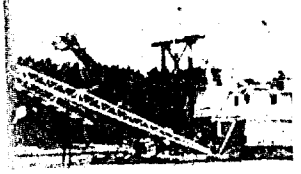

ENVIRONMENTAL LABORATORY

LONG-TERM EFFECTS OF DREDGING OPERATIONS PROGRAM

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PRELIMINARY RECOMMENDATIONS FOR A CONGENER-SPECIFIC PCB ANALYSIS IN REGULATORY EVALUATION OF DREDGED MATERIAL

by

Joan U. Clarke, Victor A. McFarland, Brian D. Pierce

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

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A preliminary recommendation of priority polychlorinated biphenyl (PCB) congeners for congener-specific analysis is offered for use in the regulatory evaluation of dredged material. Potential toxicity, environmental prevalence, and relative abundance in animal tissues are the criteria used in the selection of specific congeners and their assignment to four priority groups. Potential toxicity is equated to mammalian microsomal mixed-function oxidase (MFO) induction activity and type. MC- (3-methylcholanthrene-) type and mixed-type induction activities are considered potentially most toxic, followed by PB- (phenobarbital-) type induction activity. Weak inducers and noninducing congeners have the least potential for toxicity. Environmental prevalence, i.e., frequency of occurrence of specific congeners in environmental samples, is determined from the literature. Relative abundances of congeners (percents of total PCB as the sum of all congener concentrations) in tissues are reported or calculated from data in the literature, along

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with data generated from an experiment conducted at the US Army Engineer Waterways Experiment Station. biphenyls, phenyl compounds, chlorine compounds aspect

Eight congeners, IUPAC (International Union of Pure and Applied Chemists) Nos. 77, 118, 126, 128, 138, 156, 169, and 170, are assigned to Group 1. These congeners include the three potentially highly toxic MC-type MFO inducers, along with five mixed-type inducers that have frequently been reported in environmental samples. Group 2 congeners are PB-type MFO inducers that are also prevalent in the environment; these include numbers 87, 99, 101, 153, 180, 183, and 194. These two groups are considered most likely to contribute to any adverse biological effects associated with PCBs in an environmental sample. Group 3 congeners, Nos. 18, 44, 49, 52, 70, 74, 151, 177, 187, and 201, are weak or noninducers, but they occur frequently in the environment or in high concentrations in animal tissues relative to other PCB congeners, and thus may be of concern. Of possible importance are congeners 37, 81, 105, 114, 119, 123, 157, 158, 167, 168, and 189. These Group 4 congeners are mixed-type inducers that have been reported infrequently and in relatively low tissue concentrations.

Preface

This research was conducted by the US Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL), Vicksburg, Miss. Funding was provided by the Long-Term Effects of Dredging Operations (LEDO) Program, Work Unit 31772. The LEDO Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is managed within the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, Manager, and Mr. Russell F. Theriot, LEDO Coordinator. The Technical Monitors were Drs. Robert W. Pierce and William L. Klesch, OCE, and Mr. Charles W. Hummer, Water Resources Support Center.

Authors of this report were Ms. Joan U. Clarke, Mr. Victor A. McFarland, and Mr. Brian D. Pierce of the Contaminant Mobility and Regulatory Criteria Group (CMRCG), Ecosystem Research and Simulation Division (ERSD), EL. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

Principal Investigator was Mr. Victor A. McFarland, leader of the Aquatic Bioaccumulation/Toxicology Team, CMRCG. The study was conducted under the general supervision of Dr. Charles R. Lee, Chief, CMRCG, and Mr. Donald L. Robey, Chief, ERSD. Chief of EL was Dr. John Harrison.

Chemical analyses of polychlorinated biphenyls were done by New York University Medical Center, Institute of Environmental Medicine, Tuxedo, N. Y., under Interagency Agreement WES-CW-86-115. Dr. Joseph M. O'Connor and Mr. John Samuelian are thanked for conducting the analyses under this agreement. Ms. Wanda A. Boyd, Louisiana State University, Center for Wetland Studies, is thanked for her technical assistance in the laboratory aspects of this experiment.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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Contents

	Page
Preface	1
Introduction	3
Experimental Methods and Materials	4
Toxicity and Toxicology of PCBs	6
Toxicity to aquatic biota	6
Mixed-function oxidase induction by PCBs	9
Molecular structure and PCB congener toxicity	10
Pure 3-methylcholanthrene-type inducers	10
Mixed-type inducers	11
Priority PCB Congeners: Recommendations	12
Regulatory Evaluation of PCB-Contaminated Dredged Material	26
Summary	27
References	28
Appendix A: Numbering of PCB Congeners	A1

PRELIMINARY RECOMMENDATIONS FOR A CONGENER-SPECIFIC PCB ANALYSIS IN REGULATORY EVALUATION OF DREDGED MATERIAL

Introduction

1. Because polychlorinated biphenyls (PCBs) are widespread in the environment, are persistent, and have the potential for causing adverse biological effects, they are among the neutral organic chemicals most frequently of concern as sediment contaminants. However, many of the 209 theoretically possible PCB congeners have never been reported in environmental samples, are not toxic, or have low bioavailability. Analysis of PCBs as total PCB or as equivalents of technical PCB formulations such as Aroclors yields little information about the potential biological significance of the particular mixture of congeners in a sample. Brown et al. (1984) noted that analysis of PCBs in samples from the Hudson River, New York, as Aroclor equivalents could lead to substantial qualitative and quantitative errors. Schwartz, Stalling, and Rice (1987) showed that PCBs in fish and turtles would have been erroneously reported if analyzed as Aroclors or Aroclor equivalents, and recommended that such analyses be reported in terms of total PCB concentrations. McFarland, Clarke, and Gibson (1986) noted that nontoxic monochlorobiphenyls constituted as much as one third of the total PCB in their samples of water, sediment, clams, and fish, and such samples, if reported as total PCB, would be considered potentially more toxic than warranted

2. Congeners most likely to be of concern are members of the moderately chlorinated isomer groups (those having five to seven chlorine atoms per molecule). These congeners are generally metabolized and eliminated less readily than the lower chlorinated PCBs, but are more bioavailable than the highly chlorinated PCBs. Furthermore, the moderately chlorinated isomer groups were synthesized in high proportions in many commercial Aroclor formulations, and thus are likely to be prevalent in the environment. The moderately chlorinated isomer groups also contain the majority of mixed-function oxidase (MFO) inducing congeners, including two of the three MC- (3-methylcholanthrene-)

type inducers and all but two of the mixed-type inducers.* McFarland, Clarke, and Gibson (1986) recommended analysis of PCBs as totals in isomer groups as a more meaningful interim procedure than analysis as Aroclors or as total PCB. In this way, attention could be focused on the important penta-, hexa- and heptachlorobiphenyl isomer groups. The ultimate goal would be the development of a feasible congener-specific analytical protocol.

3. Chemical synthesis and quantitation of all 209 PCB congeners has only recently been accomplished (Mullin et al. 1984; Safe, Safe, and Mullin 1985). However, congener-specific analysis of all 209 PCBs, although possible, is neither practical nor desirable for routine regulatory evaluations. Thus, an essential step in the development of a regulatory congener-specific analytical protocol is a decision regarding the appropriate PCB congeners for inclusion in the analytical standard. The purpose of this paper is twofold. First, to present a rationale for determining the appropriateness of specific PCB congeners for inclusion in an analytical standard intended for application to environmental matrices. Second, to apply the rationale to data generated in this laboratory, or available in the literature, and by so doing to propose a prioritized list of PCB congeners for inclusion in a congener-specific analysis. Environmental prevalence, relative abundance in animal and human tissue samples, and potential toxicity are components of the rationale used herein for determining the importance of individual congeners. Based on this rationale, 36 specific PCB congeners are assigned to four priority groups and suggested for use in the ecological evaluation of dredged material.

4. Numbering of congeners in this paper follows the convention proposed by Ballschmiter and Zell (1980) and later adopted by the International Union of Pure and Applied Chemists (IUPAC). IUPAC number, structure, and isomer group are given for each congener in Appendix A.

Experimental Methods and Materials

5. Sexually immature fathead minnows, *Pimephales promelas*, were exposed continuously for 77 days to PCB-contaminated harbor sediment deposited in

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* Classification of congeners according to MFO enzyme-inducing capability is based on the following references: Goldstein et al. (1977), Goldstein (1979), Parkinson et al. (1980, 1981, 1983), Albro and McKinney (1981), and Safe et al. (1982, 1985).

aquaria of a flow-through system. Aquarium water was held at a constant temperature of 20° C, with a rate of water addition equivalent to 95 percent replacement in 12 hr. Minnows were kept separated from deposited sediment by stainless steel mesh partitions in the water column. The design ensured that fish had no direct contact with the sediment, in order to provide uniform exposures among the replicates. The aquarium design produced active interchange between the water column and the deposited-sediment surface while preventing suspension of sediment macroparticulates. The experiment was intended to provide long-term exposure of fish to PCB-contaminated sediment for at least 100 days. However, on day 77, the condition of the fish had declined and the experiment was terminated. Pooled samples consisting of five fish each were taken from three replicate aquaria on day 77 of the experiment and analyzed for specific PCB congeners.

6. Sediment and tissue samples were placed in 250-ml flasks and extracted with 125-ml hexane in an ultrasonic waterbath for 20 min. Following sonication, solids were allowed to settle and the hexane fraction was decanted. The procedure was repeated twice with the hexane fraction being collected in a separatory funnel after paper filtration. Solids were washed into the filter with hexane, and the sample was cleaned on florisil.

7. Analysis of PCB congeners was done on a Varian 3700 gas chromatograph (GC) with electron capture detection equipped with a single 30-m Chrompak C-87 (Apiezon) capillary column. The instrument was calibrated using Aroclor 1016 and 1254 standards plus 30 additional pure PCB congeners. The PCB congeners were chosen based on commercial availability, toxicological relevance, and chromatographic resolution. Relative response factors (RRFs) were determined for the 30 pure congeners; RRFs were calculated for the remaining peaks and matched with those reported by Mullin et al. (1984). Samples were run using a program that held at 190° C for 2 min, then increased at 1° C per minute to 225° C and held for 15 min. Lower detection limits varied by congener and ranged from 0.002 to 0.01 ng/g (parts per billion). Congener identifications were confirmed by Dr. John F. Brown, Jr., General Electric Company, Schenectady, N. Y.

Toxicity and Toxicology of PCBs

Toxicity to aquatic biota

8. A case for acute toxicity of PCBs to aquatic biota in the natural environment is not supported in the literature. The writers of the water quality criteria document for PCBs (US Environmental Protection Agency 1980) noted that problems could possibly exist with the validity of PCB acute toxicity tests because of the low solubility of these compounds in water, and that the solubilities of PCBs are less than their acute toxicities. McCarthy and Burton (in preparation) exposed daphnid neonates and fathead minnow fry to saturated aqueous solutions of pure individual PCB congeners. The solutions were produced using a generator column and did not employ a carrier, such as acetone, as was typically used in earlier work (Lowe et al. 1972; Hansen, Parrish, and Forester 1974; Nebeker and Puglisi 1974). No mortalities were observed that were attributable to PCB toxicity in 48- to 96-hr static replacement bioassays.

9. These results are consonant with the results of Abernethy et al. (1986), who tested the toxicity of a series of hydrocarbons and chlorohydrocarbons to *Daphnia magna* and *Artemia salina* and found that water solubility is the primary determinant of acute toxicity. Abernethy et al. (1986) also noted that since there is a trend for larger molecules to be less soluble in octanol than are smaller molecules, they also may be less "soluble" in the lipids and phospholipids of organisms. Such large-volume molecules (as, for example, the PCBs) may also partition less easily into the sites of toxic action within or on the surface of cells. Another possible factor influencing acute toxicity of large neutral molecules is a kinetic one. Larger molecules may take longer to establish concentrations necessary to produce toxic manifestations because of their lower diffusivity in water and lipid phases, and because transport occurs through aqueous phases in which they can only establish lower concentrations than can smaller molecules.

10. Ecotoxic effects of sediment PCB contamination appear most likely to be sublethal and chronic, and to be manifested at the population level in aquatic biota. Physiological functions that are controlled by steroid hormones may be altered by exposure of organisms to PCBs (Matthews et al. 1978; Fries and Lee 1984; Lee, in press). Growth, molting, and reproduction are primary functions that have been shown to be affected by exposure of aquatic

organisms to PCBs in numerous laboratory investigations. The ability of organisms to eliminate foreign organic compounds or endogenous waste products may also be affected. Steroid biosynthesis and degradation, and biotransformation of foreign compounds are metabolic activities that are strongly influenced by terminal oxidase activities of the microsomal cytochrome P-450 systems (referred to also as MFO systems). These activities occur in both fish and higher vertebrates, and it is now thought, invertebrates as well. Some, although not all, PCB congeners are inducers of MFO in fish, mammals, and birds, and to a lesser extent, in aquatic invertebrates.

11. It is primarily through effects on these enzyme systems that toxicities attributable to low concentrations of PCBs typical of environmental systems are thought to occur. Gruger et al. (1975) reported inhibited growth in juvenile salmon exposed to a tetrachlorobiphenyl (IUPAC No. 77) and two hexachlorobiphenyl congeners (IUPAC Nos. 153 and 155). Growth of minnows fed food contaminated with a technical PCB formulation, Clophen A50, was stimulated at high doses (Bengtsson 1980) and the author inferred an effect on hormones active during a diapause period, or perhaps an effect on thyroid or pituitary activity. Mauck, Mehrle, and Mayer (1978) reported significantly impaired growth and bone development in brook trout fry at 48 days after hatching. Although these and other referenced exposures were conducted at PCB concentrations substantially above those likely to be encountered in the environment, Aroclor 1254 residues in fish from the lowest exposure concentrations of Mauck, Mehrle, and Mayer (1978) were within the range found in fish under natural conditions. The authors speculated that the observed adverse effect on bone development was a realistic indication of a potential ecotoxic impact of Aroclor 1254 in the case of brook trout, and perhaps other fish species.

12. Molting of fiddler crabs has been reported to be severely impaired in laboratory exposures to Aroclor 1242 and to octachlorodibenzofuran (Fingerman and Fingerman 1977). Juvenile commercial crabs, *Callinectes sapidus*, exposed to suspensions of an inner harbor sediment containing PCBs as well as petroleum hydrocarbons, metals, and other contaminants, were deformed and died during molting (Peddicord and McFarland 1976). Lee (in press) observed that in crustaceans, ovarian development and the molt cycle are closely linked. The molting agent, ecdysone, is a steroidal hormone related structurally to androgens and estrogens. Presumably, a contaminant that causes a dysfunction

in steroid biosynthesis, and/or biotransformation and degradation, could result in impaired molting and reproductive success of aquatic organisms.

13. Recent work at the US Army Engineer Waterways Experiment Station (WES) (Dillon and Benson, in preparation) with PCB-contaminated sediment and with selected pure PCB congeners has focused on reproductive success in fathead minnows. In experiments in which minnows were preexposed to contaminated sediment for 7 weeks and then induced to spawn, reproduction was significantly impaired. Separate exposure to pure PCB congeners selected for expected potency as MFO inducers did not result in any impairment of reproduction. Fries and Lee (1984) exposed marine polychaetes, *Nereis virens*, to the procarcinogenic aromatic hydrocarbon, benzo[a]pyrene, and to Aroclor 1254 in food, and found significantly elevated MFO activity. Feral *N. virens* were then collected from clean reference and oil-contaminated sites. The worms from the oil-contaminated sites had MFO activities approximately six times greater than those from the reference site, and were one-sixth the body weight of the reference site worms. Work reported by Spies, Felton, and Dillard (1982) and Spies et al. (1985) correlated elevated MFO activities and reproductive failure in flatfish with PCB and oil ingestion, and with elevated PCB concentrations in sediments at the collection sites.

14. A major difficulty encountered in interpreting the relevance of findings such as the above to PCB contamination in sediments is a lack of clear causal relationships. Aquatic organisms in natural circumstances are almost always exposed to a variety of interacting contaminants. The interactions may be additive, synergistic, or antagonistic. In addition, the data regarding toxicity to aquatic biota of individual PCB congeners is scant and frequently seems contradictory. In contrast, the evidence for PCB toxicity to higher vertebrates, including humans, is less ambiguous. The relative potencies of many of the congeners are known, and some structure-activity relationships are established. PCBs as contaminants of fish and shellfish are a concern to the health of human consumers, as well as for the protection of avian and terrestrial wildlife. Therefore, the approach taken in this paper relies on toxicological properties of PCB congeners in mammalian and avian systems as a factor in the recommendation of specific congeners for analysis.

Mixed-function oxidase induction by PCBs

15. Enzymes of the MFO systems in birds and higher vertebrates, including humans, fall in two major classifications. The MFO systems are frequently characterized by reference to model chemicals that induce or inhibit them. The MFO system that is induced by phenobarbital (PB) and similar molecules (PB-type inducers) is primarily involved with detoxication of lipophilic foreign compounds and endogenous substances such as steroids. These enzymes catalyze the insertion of oxygen into conformationally nonhindered sites of globular molecules (such as phenobarbital), thus facilitating their conjugation and removal (Parke 1985). This oxygenation is the first phase of a two-phase metabolic process. Ordinarily, reactions catalyzed by PB-inducible enzymes in Phase I detoxication go on to conjugation with endogenous substrates such as glutathione, glutamic acid, or sulfate in Phase II. Conjugation renders the lipophilic molecule soluble and thus more easily excreted.

16. The second main class of MFOs is induced by planar molecules conformationally similar to the model chemical 3-methylcholanthrene (MC-type inducers). These MFOs are capable of bioactivation of procarcinogens, such as benzo[a]pyrene, to active carcinogens and mutagens. Two enzymes of this class are frequently referenced, and their presence identifies MC-type activity. These are aryl hydrocarbon hydroxylase (AHH, also called benzo[a]pyrene hydroxylase) and ethoxyresorufin *O*-deethylase (EROD). The MC-inducible MFOs function to insert oxygen into conformationally hindered sites of planar molecules, including the "bay region" positions of polynuclear aromatic hydrocarbons (Parke 1985). Conformational hindrance of the oxygenated molecule provides stability and tends to inhibit the conjugation and detoxication that usually occurs readily in the case of PB-type enzymic action. Since reactive epoxides are formed as transition products by both PB- and MC-type enzymes, both systems have the potential for producing toxicity through bioactivation, if the formation of epoxides exceeds the capacity of the conjugating systems for detoxication.

17. The MFOs of fish, and apparently of aquatic invertebrates, are qualitatively similar to the MC-type MFOs of vertebrates (Sieber and Adamson 1977; Parke 1985; Stegeman and Kloepper-Sams 1987; Lee, in press). Phenobarbital-type induction has been reported in mummichog, rainbow trout, and carp in a few investigations, but these are greatly outnumbered by studies that have not demonstrated PB-type induction in fish (Kleinow, Melancon, and Lech 1987).

Quantitatively, the detoxifying capability of fish appears to be about one tenth that of mammals (Sieber and Adamson 1977). The enzymes AHH and EROD are characteristic of fish MFOs as well as of mammals.

Molecular structure and PCB congener toxicity

18. The toxicity of individual PCB congeners is directly relatable to the nearness with which they approach the molecular spatial configuration and distribution of forces of the 2,3,7,8-tetrachlorodibenzo-*p*-dioxin molecule (2,3,7,8-TCDD). The dioxin, 2,3,7,8-TCDD, is considered the most potent synthetic environmental toxin known, and is taken as the standard against which structurally similar molecules, such as some PCB congeners, can be compared (Safe 1987). Dioxins are coplanar biphenylic molecules; i.e., the nucleus of a dioxin is composed of two phenyl rings bound in such a way that the rings lie spatially in the same plane. Coplanarity is a characteristic of aromatic molecules that increases lipid solubility and potential for toxicity.

19. The most toxicologically active PCB congeners are those that are chlorine-substituted at both *para* (4 and 4') and at least two *meta* (3, 3', 5, and 5') positions on the biphenyl nucleus, and that do not contain any *ortho* (2, 2', 6, and 6') substitutions (Safe et al. 1985). Because the phenyl rings of a biphenyl nucleus are linked by a single covalent carbon:carbon bond, the two rings have relatively unconstrained rotational freedom. Chlorines are bulky atoms, and the substitution of a chlorine at certain positions on the biphenyl nucleus inflicts constraints on rotational freedom. The greatest effect is exerted by substitution at the *ortho* positions, and the larger the number of *ortho* substitutions (one to four), the greater the probability of the molecule lying outside a coplanar configuration.

Pure 3-methylcholanthrene-type inducers

20. Molecules that have no *ortho* substitutions tend toward a coplanar configuration. The structure-activity rule mentioned above limits the number of PCB congeners that are toxicologically most active to four. The congeners that satisfy the rule are Nos. 77, 81, 126, and 169 (Appendix A). In fact, with the exception of No. 81, these congeners are demonstrably potent inducers of AHH and EROD in *in vitro* rat hepatoma preparations, and the *in vitro* induction of these enzymes correlates strongly with *in vivo* demonstrations of toxicity in mammals, e.g., thymic atrophy and inhibition of body weight gain (Sawyer and Safe 1982, Safe 1987). Congeners 77, 126, and 169 are pure

MC-type inducers and approach the toxic potency of 2,3,7,8-TCDD. Tanabe et al. (1987) reported the presence of congeners 77, 126, and 169 in tissue samples from a wide range of organisms including marine mammals and humans. Residues of congeners 77, 126, and 169 were present in sufficiently high concentrations for the authors to conclude that these three toxic coplanar PCBs, and particularly No. 126, pose a greater threat to humans and wildlife than does 2,3,7,8-TCDD itself.

21. The conclusion of Tanabe et al. (1987) was made on the basis of "toxic equivalents," i.e., the product of molar concentration and potency for AHH or EROD induction relative to 2,3,7,8-TCDD in *in vitro* rat hepatoma tissue cultures (Safe 1987). Whether this conclusion will prove correct remains to be seen. The results of recent investigations by Safe and coworkers (Safe et al. 1987) have indicated that the PCB mixture, Aroclor 1254, is a dioxin antagonist in C57BL/6J mice if administered at noneffective (below toxic threshold) doses. The mechanism is thought to be competitive inhibition in which larger concentrations of sterically similar but less effective PCB congeners outcompete 2,3,7,8-TCDD for the same cytosolic receptor sites. The implications for environmental effects are substantial. If this instance of competitive inhibition is a generally operant mechanism in biota, it could provide insight into the ability of most adult organisms, including fish and shellfish, to carry seemingly large body burdens of dioxins, furans, and PCBs without apparent effect.

22. Safe et al. (1985) noted that two lower chlorinated congeners, the dichlorobiphenyl No. 15 and the trichlorobiphenyl No. 37, are also coplanar. However, No. 15 exhibits weak PB-type induction, while No. 37 is a mixed-type inducer of less potency than No. 81.

Mixed-type inducers

23. The second set of congeners having enzyme-inducing potencies and toxicities of high concern are the analogs of congeners 77, 81, 126, and 169 that are still relatively coplanar but have a single *ortho*-chloro substitution. These are congeners 105, 114, 118, 123, 156, 157, 167, and 189. This group of congeners has demonstrated mixed PB- and MC-type inducing properties. Of these, congener 105 is often present in appreciably high concentrations in sediments, but analyses of aquatic organism tissues do not reflect this abundance. It is probable that this congener is rapidly metabolized by aquatic organisms. Safe (1987) noted that congener 105 did not conform to the close

relationship between in vitro and in vivo effects characteristic of most of the others of this group. The presence of adjacent unsubstituted carbons in the biphenyl nucleus of this molecule facilitates metabolic degradation.

24. The di-*ortho* coplanar PCB molecules (having two *ortho*-substituted chlorines) are congeners 128, 137, 138, 153, 158, 166, 168, 170, 180, 190, 191, 194, and 205. Some of these (Nos. 128, 138, 158, 166, 168, and 170) have been shown to be mixed-type inducers in mammals, although less potent than the coplanar and mono-*ortho* coplanar congeners (Safe et al. 1985). The remaining di-*ortho* coplanar congeners are PB-type inducers. Numbers 138 and 153 are major components of technical PCB formulations and appear to have the greatest potency among the di-*ortho* coplanar congeners, both as inducers and as toxins.

25. Besides the di-*ortho* coplanar PB-type inducers mentioned above, there are other congeners that have been demonstrated to induce PB-type MFOs, along with congeners that may be theoretically classified as PB-type inducers according to structure-activity rules proposed by Parkinson and coworkers (Parkinson, Cockerline, and Safe 1980; Parkinson et al. 1980, 1981; Safe et al. 1982) (see Clarke 1986). The majority of PCB congeners apparently have no effect on mammalian systems. We must consider the MC-type and mixed-type inducer PCBs as having the highest potential for toxic effect in mammals, birds, and possibly fish and aquatic invertebrates.

26. The rat hepatoma cell line used in the in vitro bioassessment of the potencies of single PCB congeners as inducers and toxins provides a model that permits comparisons. It is a far leap from this model to actual effects that are observed in the field, where mixtures of PCB congeners and a vast number of other chemicals are present in sediments, and are absorbed, ingested or otherwise encountered by aquatic organisms and the avian and terrestrial fauna that prey on them. At this juncture we simply do not know the final meaning of environmental contamination by PCBs. The contamination is indisputable. The significance of the contamination is not clear. Thus, the following recommendations of important PCB congeners, which are based in part on toxicological activity, can only be considered tentative.

Priority PCB Congeners: Recommendations

27. Specific PCB congeners recommended for use in the regulatory evaluation of dredged material are selected and assigned to priority groupings based on three factors:

a. Potential for toxicity.

b. Frequency of occurrence in environmental samples.

c. Relative abundance in animal tissues.

28. Potential for toxicity is inferred by microsomal MFO inducer type. MC-type and mixed-type inducers are considered to be potentially more toxic than PB-type inducers, which are considered potentially more toxic than weak inducers and noninducers.

29. Frequency of occurrence in environmental samples is determined from a PCB congener data base (J. Clarke,* unpublished) developed from information reported in the scientific literature. Environmental samples refer to sediments, water, or organisms collected in the field, as opposed to samples resulting from laboratory exposures to PCBs. At present, 59 literature references included in the data base report information on specific PCB congeners in environmental samples. Congeners are considered to occur frequently if reported by at least 20 percent (11 of 59) of the references listing specific congeners in environmental samples.

30. Several sources were used for information on the relative abundance of specific congeners in animal tissues. A total of 41 single congeners and 6 mixtures of congeners that were evidenced by a set of overlapping peaks from GC analysis (i.e., "mixed peaks") were quantitated in fathead minnows from the experiment described herein. Smith et al. (1985) quantitated 72 congeners in oligochaetes, carp, and ducks from the Detroit River, Michigan. Duinker and Hillebrand (1983) reported percent of total PCB for 43 congeners and 11 mixed peaks in samples of seston, shrimp, plaice, and porpoise from the Dutch Wadden Sea. Bush et al. (1985) quantitated 36 congeners and 2 mixed peaks in caddisfly larvae from the upper Hudson River, New York. Safe, Safe, and Mullin (1985) analyzed for all 209 congeners in composited human milk samples from Michigan, and reported percent of total PCB for each congener found. Finally, Jensen and Sundström (1974) reported percent of total PCB for 55 congeners in human adipose tissue from people living in southwestern Sweden. Table 1 presents relative abundances of specific congeners in tissues as percent of total PCB reported or calculated from the above sources. When congeners were

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* Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Table 1

PCB Congeners: Frequency of Environmental Occurrence and Relative Abundance in Animal and Human Tissues

IUPAC No.	Isomer Group**	Inducer Type†	Environmental Occurrences††	Percent of Total PCB in Sample*										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
1	1		3	-	-	-	-	-	-	-	-	1.2	0	-
2	1		1	-	-	-	-	-	-	-	-	-	0	-
3	1		1	-	-	-	-	-	-	-	-	-	0	-
4	2		5	0	0	3.8	0.17	-	-	-	-	3.8	0	-
5	2		4	1.2	-	-	-	1.6[a/]	0	0	0	-	0	-
6	2		3	0.55	-	-	-	0	-	-	-	0.27	0	-
7	2		3	-	0	0.09	0.11	-	-	-	-	-	0	-
8	2		4	0.09	-	-	-	1.6[a/]	0	0	0	0.86	0	-
9	2		2	0.17	-	-	-	-	-	-	-	-	0	-
10	2		2	-	-	-	-	-	-	-	-	-	0	-
11	2	wk PB	1	-	-	-	-	-	-	-	-	-	0	-
12	2		1	-	-	-	-	-	-	-	-	-	0	-
13	2		1	-	-	-	-	-	-	-	-	-	0	-
14	2	wk PB	0	-	-	-	-	-	-	-	-	-	0	-
15	2	wk PB	5	2.1	-	-	-	2.1	0.8	0	0	0.94[b/]	0	-
16	3		5	0	-	-	-	-	-	-	-	0.13[b/]	0	-
17	3		6	4.0	1.0	2.1	0	-	-	-	-	1.1	0	-
18	*3*		*13*	*0.93*	*1.4*	*0.87*	*0.17*	*2.1*	*0.5*	*0*	*0*	*2.2*	*0*	-

(Continued)

* Total PCB = sum of individual congener concentrations; fathead minnows data from this experiment; oligochaetes, carp, and ducks data from Smith et al. (1985); seston, shrimp, plaice, and porpoise data from Duinker and Hillebrand (1983); insect (caddisfly) larvae percents averaged from Bush et al. (1985); human milk data from Safe, Safe, and Mullin (1985); human fat data from Jensen and Sundström (1974).

** Isomer groups are defined by the number of chlorine atoms in the molecule.

† wk PB = weak phenobarbital-type or inactive microsomal enzyme inducers, mixed = mixed phenobarbital- and 3-methylcholanthrene-type, PB = phenobarbital-type, MC = 3-methylcholanthrene-type, PB* = theoretical phenobarbital-type according to structure-activity rules (see Clarke 1986).

†† Number of references (out of 57 literature references giving information on PCB congeners) reporting occurrence in environmental samples.

a/ Coeluting congeners reported by Duinker and Hillebrand (1983): 5 and 8; 28 and 50; 21, 33 and 53; 47 and 75; 37 and 42; 70, 80 and 96; 95 and 66; 87, 90 and 116; 110 and 77; 149 and 123; 202 and 193.

b/ Mixed-congener peaks reported by Bush et al. (1985): 16 and 27; 20 and 28.

c/ Chromatographic analysis of samples from this experiment did not resolve peaks corresponding to congeners 20 and 28, 82 and 85, or 141 and 153.

d/ Mixed-congener peaks reported by Safe, Safe, and Mullin (1985): 56 and 60; 70 and 76; 135 and 144; 171 and 202.

Table 1 (Continued)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
19	3		2	-	-	-	-	2.6	0	0	0	--	0	-
20	3		5	6.1[c]	-	-	-	-	-	-	-	2.4[b]	0	-
21	3		2	-	-	-	-	1.4[a]	0	0	0	-	0	-
22	3		6	0.80	0.36	0.13	0.03	-	-	-	-	4.8	0.65	-
23	3		0	-	-	-	-	-	-	-	-	-	0	-
24	3		2	-	-	-	-	2.1	0	0	0	-	0	-
25	3		4	9.9	-	-	-	-	-	-	-	3.2	0	-
26	3		8	7.5	0	0.38	0.05	2.8	7.8	1.1	0.6	1.1	0	-
27	3		4	-	-	-	-	-	-	-	-	0.13[b]	0	-
28	3		10	6.1[c]	-	-	-	1.4[a]	1.2[a]	0.3[a]	0	2.4[b]	8.8	-
29	3		2	-	-	-	-	2.1	0	0	0	-	0	-
30	3		0	-	-	-	-	-	-	-	-	-	0	-
31	3		4	-	5.6	2.1	5.7	1.4	1.0	0.4	0	-	0	-
32	3		4	1.1	-	-	-	-	-	-	-	3.2	0	-
33	3		5	-	1.6	0.54	0.20	1.4[a]	0	0	0	-	2.2	-
34	3		4	6.2	-	-	-	-	-	-	-	-	0	-
35	3		0	-	-	-	-	-	-	-	-	-	0	-
36	3		2	-	-	-	-	-	-	-	-	-	0	-
37	*3*	*mixed*	*5*	-	-	-	-	*2.1*[a]	*1.0*[a]	*0.2*[a]	*0*	-	*2.9*	-
38	3		0	-	-	-	-	-	-	-	-	-	0	-
39	3		1	-	-	-	-	-	-	-	-	-	0	-
40	4		7	1.2	0	0.24	0.06	1.4	1.4	0.2	0	-	0	-
41	4		7	-	-	-	-	1.4	2.2	0.3	0	-	1.3	0.66
42	4		5	-	0.77	0.57	0.06	2.1[a]	1.0[a]	0.2[a]	0	-	0	-
43	4		1	-	0	0.12	0.02	-	-	-	-	-	0	-
44	*4*		*17*	*5.8*	*1.8*	*1.5*	*0.09*	*2.1*	*2.8*	*0.5*	*0*	*19.6*	*0.78*	*1.1*
45	4		2	-	0.45	0.27	0	-	-	-	-	-	0	-
46	4		3	-	0.29	0.08	0.06	-	-	-	-	-	0.25	-
47	4	PB	8	3.8	0.70	0.82	0.97	4.9[a]	0.4[a]	1.0[a]	0.2[a]	3.1	0	-
48	4		3	-	0.41	0.34	0.23	-	-	-	-	-	0.37	-
49	*4*		*15*	*7.6*	*1.6*	*2.0*	*0.31*	*2.8*	*4.4*	*0.9*	*0.7*	*4.0*	*0.66*	*0*
50	4		3	0	-	-	-	1.4[a]	1.2[a]	0.3[a]	0	1.6	0	-
51	4		3	-	-	-	-	-	-	-	-	-	0	-
52	*4*	*wk PB*	*18*	*11.9*	*2.7*	*2.7*	*0.37*	*2.1*[a]	*8.5*	*4.2*	*4.1*	*13.6*	*1.9*	*0*
53	4		2	-	0.56	0.28	0.02	1.4[a]	0	0	0	-	0	-
54	4	wk PB	2	-	-	-	-	-	-	-	-	-	0	-

(Continued)

Table 1 (Continued)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
55	4		0	-	-	-	-	-	-	-	-	-	0	-
56	4		2	1.2	-	-	-	-	-	-	-	-	0.71[d]	-
57	4		1	-	-	-	-	-	-	-	-	-	0	-
58	4		2	-	-	-	-	-	-	-	-	-	0	-
59	4		1	-	-	-	-	-	-	-	-	-	0	-
60	4		7	-	-	-	-	1.4	0.5	0.6	0	-	0.71[d]	-
61	4		3	-	-	-	-	0.7	1.2	0.8	0.1	-	0	-
62	4		0	-	-	-	-	-	-	-	-	-	0	-
63	4		2	-	0	0.16	0.27	-	-	-	-	-	0	-
64	4		5	-	0.65	1.1	0.12	-	-	-	-	-	0	0.56
65	4		0	-	-	-	-	-	-	-	-	-	0	-
66	4	PB	7	1.0	-	-	-	3.5[a]	6.9[a]	4.0[a]	2.9[a]	3.9	0	-
67	4		2	-	-	-	-	-	-	-	-	-	0	-
68	4		1	-	-	-	-	-	-	-	-	-	0	-
69	4		0	-	-	-	-	-	-	-	-	-	0	-
70	*4*		*13*	-	*2.0*	*0.93*	*0.42*	*4.9*[a]	*6.0*[a]	*3.4*[a]	*0*	*6.1*	*0.61*[d]	*1.5*
71	4		1	-	-	-	-	-	-	-	-	-	0	-
72	4		2	-	-	-	-	-	-	-	-	-	0	-
73	4		1	-	-	-	-	-	-	-	-	-	0	-
74	*4*		*4*	*5.8*	*1.1*	*1.3*	*2.5*	-	-	-	-	-	*11.0*	-
75	4	wk PB	2	-	-	-	-	4.9[a]	0.4[a]	1.0[a]	0.2[a]	-	0	-
76	4		2	-	-	-	-	-	-	-	-	-	0.61[d]	-
77	*4*	*MC*	*5*	-	-	-	-	*8.5*[a]	*0*	*16.8*[a]	*0*	*0.07*	*0*	-
78	4		0	-	-	-	-	-	-	-	-	-	0	-
79	4		1	-	-	-	-	-	-	-	-	-	0	-
80	4	wk PB	3	-	-	-	-	4.9[a]	6.0[a]	3.4[a]	0	-	0	-
81	*4*	*mixed*	*1*	-	*0.07*	*0.12*	*0.30*	-	-	-	-	-	*0*	-
82	5		6	5.7[c]	0.14	0.17	0.08	0.3	0	0.2	0.2	4.0	0	0
83	5		1	-	-	-	-	-	-	-	-	-	0	-
84	5		10	-	1.5	1.9	0.77	0.7	0.1	1.0	0.1	1.1	0	2.5
85	5	PB*	5	5.7[c]	-	-	-	-	-	-	-	2.8	0	-
86	5		3	-	-	-	-	-	-	-	-	-	0	-
87	*5*	*PB*	*12*	*2.4*	*0.61*	*1.2*	*0.14*	*0.7*[a]	*0.6*[a]	*0.4*[a]	*0.3*[a]	*2.6*	*0.82*	*1.3*
88	5		1	-	-	-	-	0	0.4	0	0.1	-	0	-
89	5		2	-	-	-	-	-	-	-	-	-	0	-
90	5		4	-	-	-	-	0.7[a]	0.6[a]	0.4[a]	0.3[a]	-	0	-
91	5		4	-	-	-	-	-	-	-	-	-	0	-

(Continued)

Table 1 (Continued)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
92	5		4	-	-	-	-	0	0.7	0.7	1.2	-	0	1.2
93	5		0	-	-	-	-	-	-	-	-	-	0	-
94	5		2	-	-	-	-	-	-	-	-	-	0	-
95	5		8	0.46	6.1	7.0	1.9	3.5[a]	6.9[a]	4.0[a]	2.9[a]	-	0	1.2
96	5		2	-	-	-	-	4.9[a]	6.0[a]	3.4[a]	0	-	0	-
97	5		10	0.47	0.41	0.34	0.14	-	-	-	-	1.4	0	0
98	5		1	-	-	-	-	-	-	-	-	-	0	0
99	*5*	*PB**	*15*	*1.6*	-	-	-	*2.1*	*6.0*	*3.3*	*3.5*	*1.6*	*4.8*	*1.9*
100	5	PB*	2	-	0.25	0.05	0.12	-	-	-	-	-	0	-
101	*5*	*PB*	*21*	*2.2*	*2.5*	*3.0*	*0.70*	*4.2*	*6.0*	*7.0*	*3.3*	*1.9*	*0.97*	*4.2*
102	5		3	-	-	-	-	-	-	-	-	-	0	-
103	5		1	-	-	-	-	-	-	-	-	-	0	-
104	5		0	-	-	-	-	-	-	-	-	-	0	-
105	*5*	*mixed*	*9*	*0.62*	-	-	-	*2.1*	*0*	*0.9*	*0*	-	*0*	*1.9*
106	5		2	-	-	-	-	-	-	-	-	-	0	-
107	5		2	-	-	-	-	-	-	-	-	-	0.31	-
108	5		2	-	-	-	-	-	-	-	-	-	0	-
109	5		1	-	-	-	-	-	-	-	-	-	0	-
110	5		6	-	-	-	-	8.5[a]	0	16.8[a]	0	-	1.0	4.7
111	5		0	-	-	-	-	-	-	-	-	-	0	-
112	5		1	-	-	-	-	-	-	-	-	-	0	-
113	5		1	-	-	-	-	-	-	-	-	-	0	-
114	*5*	*mixed*	*3*	-	*0*	*0.06*	*0.15*	-	-	-	-	-	*0.33*	-
115	5		1	-	-	-	-	-	-	-	-	-	0	-
116	5		2	-	-	-	-	0.7[a]	0.6[a]	0.4[a]	0.3[a]	-	0	-
117	5		0	-	-	-	-	-	-	-	-	-	0	-
118	*5*	*mixed*	*16*	*0.95*	*1.6*	*2.4*	*4.7*	*1.4*	*3.0*	*14.0*	*2.2*	-	*6.5*	*5.4*
119	*5*	*mixed*	*3*	-	*0*	*0.09*	*0.13*	-	-	-	-	-	*0.08*	-
120	5		2	-	-	-	-	0.7	3.0	0.5	0.3	-	0	-
121	5		0	-	-	-	-	-	-	-	-	-	0	-
122	5		2	-	-	-	-	-	-	-	-	-	0.53	-
123	*5*	*mixed*	*1*	-	-	-	-	*2.1*[a]	*1.0*[a]	*15.8*[a]	*7.0*[a]	-	*0*	-
124	5		1	-	-	-	-	-	-	-	-	-	0	-
125	5		0	-	-	-	-	-	-	-	-	-	0	-
126	*5*	*MC*	*0*	-	-	-	-	-	-	-	-	-	*0*	-

(Continued)

Table 1 (Continued)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
127	5		0	-	-	-	-	-	-	-	-	-	0	-
128	*6*	*mixed*	*13*	*0.28*	*0.47*	*0.76*	*1.7*	*1.4*	*0.2*	*0.1*	*1.6*	*0.38*	*0.33*	*0.81*
129	6		6	-	0.14	0.17	0	-	-	-	-	-	0	-
130	6		3	-	-	-	-	-	-	-	-	-	0.59	0
131	6		2	0.05	0	1.7	0.94	-	-	-	-	-	0	-
132	6		8	0.83	-	-	-	2.8	0	1.4	2.6	0.94	0	0.15
133	6	PB	3	-	-	-	-	-	-	-	-	-	0	-
134	6		6	-	0.20	0.24	0	-	-	-	-	0.13	0	0.05
135	6		4	-	-	-	-	-	-	-	-	-	0.51[d]	1.0
136	6	wk. PB	7	0.55	0.77	1.1	1.13	0	0	0.2	0.3	-	0	0
137	6	PB	8	-	1.7	0.43	0.88	-	-	-	-	-	0.87	-
138	*6*	*mixed*	*18*	*0*	*5.9*	*5.8*	*9.2*	*4.9*	*6.4*	*6.1*	*16.7*	*1.6*	*10.0*	*14.0*
139	6	PB*	1	-	-	-	-	-	-	-	-	-	0	-
140	6	PB*	1	-	-	-	-	-	-	-	-	-	0	-
141	6		9	1.1[c]	1.4	1.6	0.42	1.4	1.0	0.9	0.2	-	0.29	-
142	6		0	-	-	-	-	-	-	-	-	-	0	-
143	6		1	-	-	-	-	-	-	-	-	-	0	-
144	6		5	-	0.81	1.2	0.19	-	-	-	-	-	0.51[d]	-
145	6		0	-	-	-	-	-	-	-	-	-	0	-
146	6	wk. PB*	4	-	1.0	1.3	2.6	-	-	-	-	-	1.9	2.7
147	6		3	-	-	-	-	-	-	-	-	-	0	-
148	6		1	-	-	-	-	-	-	-	-	-	0	-
149	6		9	1.5	4.5	5.1	1.8	2.1[a]	1.0[a]	15.8[a]	7.0[a]	-	0	0.13
150	6		1	-	-	-	-	-	-	-	-	-	0	-
151	*6*	*wk. PB*	*12*	*0.87*	*2.1*	*2.1*	*0.23*	*1.4*	*6.0*	*1.9*	*2.2*	*0.50*	*0.59*	*0.43*
152	6		2	-	-	-	-	-	-	-	-	-	0	-
153	*6*	*PB*	*22*	*1.1[c]*	*9.9*	*11.1*	*18.2*	*4.2*	*6.4*	*6.6*	*22.5*	*0.54*	*12.0*	*21.5*
154	6	PB	1	-	-	-	-	-	-	-	-	-	0	-
155	6	wk. PB	0	-	-	-	-	-	-	-	-	-	0	-
156	*6*	*mixed*	*13*	*0.11*	*0.36*	*0.36*	*0.81*	-	-	-	-	*0.15*	*4.9*	*2.0*
157	*6*	*mixed*	*1*	-	-	-	-	-	-	-	-	-	*0.47*	-
158	*6*	*mixed*	*5*	-	*0.56*	*0.64*	*1.0*	-	-	-	-	*0.38*	*0.55*	-
159	6	wk. PB	2	-	-	-	-	-	-	-	-	-	0	-
160	6		0	-	-	-	-	-	-	-	-	-	0	-
161	6		1	-	-	-	-	-	-	-	-	-	-	-

(Continued)

Table 1 (Continued)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
162	6		0	-	-	-	-	-	-	-	-	-	0	-
163	6	PB	1	-	-	-	-	-	-	-	-	-	0	-
164	6		0	-	-	-	-	-	-	-	-	-	0	-
165	6	PB	1	-	-	-	-	-	-	-	-	-	0	-
166	6	mixed	0	-	-	-	-	-	-	-	-	-	0	-
167	*6*	*mixed*	*5*	*0.05*	-	-	-	-	-	-	-	-	*0.85*	*0.49*
168	*6*	*mixed*	*1*	-	-	-	-	-	-	-	-	-	*0*	-
169	*6*	*MC*	*0*	-	-	-	-	-	-	-	-	-	*0*	-
170	*7*	*mixed*	*16*	*0.12*	*5.6*	*5.2*	*8.9*	*2.8*	*1.4*	*1.1*	*3.5*	-	*5.3*	*3.9*
171	7	PB*	5	0.16	-	-	-	-	-	-	-	-	0.37[d]	0.57
172	7		8	-	0.54	0.48	0.87	-	-	-	-	-	0.31	1.2
173	7		4	-	0.07	0.06	0.03	-	-	-	-	-	0	-
174	7		8	-	2.9	2.4	1.0	1.4	0.2	0.1	1.8	-	0.39	0
175	7		2	-	0.20	0.13	0.20	-	-	-	-	-	0	-
176	7		7	0.17	1.6	0.37	0.34	0	0.3	0	0.4	2.4	0	0
177	*7*		*11*	-	*1.4*	*1.3*	*1.6*	*1.4*	*1.0*	*0.2*	*1.8*	-	*0.61*	*1.3*
178	7		4	0.43	-	-	-	-	-	-	-	-	0	0.90
179	7		7	-	-	-	-	0.5	0.2	0.9	0.3	-	0	0
180	*7*	*PB*	*15*	*0.30*	*7.0*	*7.0*	*12.0*	*3.5*	*2.0*	*1.9*	*7.5*	-	*5.3*	*7.7*
181	7	PB*	1	-	-	-	-	-	-	-	-	-	0	-
182	7	PB*	1	-	-	-	-	-	-	-	-	-	0	-
183	*7*	*PB**	*11*	-	*3.2*	*2.2*	*3.9*	*0.7*	*0.2*	*0.5*	*1.8*	-	*1.4*	*0.81*
184	7	PB*	0	-	-	-	-	-	-	-	-	-	0	-
185	7		4	-	0.41	0.45	0.16	-	-	-	-	-	0.11	-
186	7		0	-	-	-	-	-	-	-	-	-	0	-
187	*7*		*13*	-	*5.4*	*3.9*	*4.6*	*1.4*	*3.0*	*2.3*	*4.0*	-	*1.5*	*3.5*
188	7		1	-	-	-	-	-	-	-	-	-	0	-
189	*7*	*mixed*	*4*	-	*0.14*	*0.09*	*0.17*	-	-	-	-	-	*2.4*	*0*
190	7	PB	1	-	-	-	-	-	-	-	-	-	0	-
191	7	PB	3	-	0.43	0.28	0.46	-	-	-	-	-	0.90	-
192	7		1	-	-	-	-	-	-	-	-	-	0	-
193	7		4	-	0.81	0.31	0.52	0.2[a]	0.2[a]	0.2[a]	2.0[a]	-	0.19	-
194	*8*	*PB*	*12*	-	*0.77*	*0.58*	*1.4*	*0.6*	*0.1*	*0*	*1.8*	-	*0.48*	*1.7*
195	8	PB	9	-	0.38	0.33	0.65	-	-	-	-	-	0.31	0.31
196	8	PB*	8	-	-	-	-	0.6	0.2	0.1	1.8	-	0.18	0.94

(Continued)

Table 1 (Concluded)

IUPAC No.	Isomer Group	Inducer Type	Environmental Occurrences	Percent of Total PCB in Sample										
				Fathead Minnows	Oligochaetes	Carp	Ducks	Seston	Shrimp	Plaice	Porpoise	Insect Larvae	Human Milk	Human Fat
197	8	PB*	0	-	-	-	-	-	-	-	-	-	0	0
198	8		7	-	0.61	0.17	0.28	-	-	-	-	-	0	-
199	8		3	-	0.07	0.03	0.01	-	-	-	-	-	0	0
200	8		3	-	-	-	-	-	-	-	-	-	0	0
201	*8*		*11*	-	*1.7*	*1.3*	*2.4*	*0.7*	*0.2*	*0*	*1.5*[a/]	*0.22*	*0.85*[d/]	*0.77*
202	8		7	-	0.54	0.55	0.76	0.2[a/]	0.2[a/]	0.2[a/]	2.0[a/]	-	0.37[d/]	0
203	8	PB*	3	-	-	-	-	-	-	-	-	-	0.79	0.46
204	8	PB*	1	-	-	-	-	-	-	-	-	-	0	-
205	8	PB	2	-	0.11	0.04	0.08	-	-	-	-	-	0.06	-
206	9	PB*	6	-	0.29	0.12	0.35	0.1	0	0	0.4	-	0.24	-
207	9	PB*	2	-	0.02	0.01	0.03	-	-	-	-	-	0	0
208	9		1	-	-	-	-	-	-	-	-	-	0	0
209	10	PB*	5	-	-	-	-	0.5	0.1	0	0.3	-	0.09	0.62

expressed as concentrations rather than as percent of total PCB, percents were calculated from total PCB as the sum of the reported individual congener and mixed-peak concentrations.

31. Table 1 contains information for all 209 PCB congeners. Those congeners considered important by the criteria listed above are italicized in Table 1 and are grouped according to priority in Table 2.

32. Group 1, the highest priority congeners, are those that are most likely to contribute to any adverse biological effects attributable to PCBs in an environmental sample. Group 1 congeners fall into two classifications. Group 1A comprises the three MC-type inducers, Nos. 77, 126, and 169. All three have been reported in environmental samples (Tanabe et al. 1987), albeit infrequently and in low concentrations (parts per trillion in fish, marine mammal, and terrestrial mammal tissues). However, Tanabe and coworkers have suggested that these coplanar congeners, especially No. 126, pose a greater toxic threat than dioxins and furans to humans and wildlife. Although the coplanar PCBs are less potent as enzyme inducers than the most toxic dioxins and furans, they have been reported in much higher concentrations in tissues (Tanabe et al. 1987). All three congeners have been identified as minor components of some technical PCB formulations (Albro, Corbett, and Schroeder 1981; Tanabe et al. 1987).

33. Group 1B congeners, Nos. 118, 128, 138, 156, and 170, are all mixed-type inducers that have been reported numerous times in environmental matrices. These congeners occur in nearly all of the samples included in Table 1 and individually represent as much as 16 percent of total PCB reported in animal tissues. Collectively, Group 1 congeners comprise 24 to 27 percent of total PCB in the birds and mammals of Table 1, with lesser representation (as little as 1.5 percent) in the fish and invertebrate samples.

34. Group 2 consists of known and theoretical PB-type MFO inducers that have numerous reported environmental occurrences. These include Nos. 87, 99, 101, 153, 180, 183, and 194. Group 2 congeners, like those of Group 1B, occur in most of the samples in Table 1, and individually compose up to 22 percent of total PCB in animal tissues. As a group, these congeners contribute 26 to 41 percent of total PCB in the bird and mammal samples, and 7 to 25 percent of total PCB in fish and invertebrates.

35. All of the congeners in Groups 1 and 2 are members of the penta-, hexa-, and heptachlorobiphenyl isomer groups, except No. 77, a

Table 2

Priority Groups of Important PCB Congeners
Recommended for Use in the Regulatory Evaluation
of PCB-Contaminated Dredged Material

Group 1 IUPAC No.	Group 2 IUPAC No.	Group 3 IUPAC No.	Group 4 IUPAC No.
A	87 *	18 *	37
	99	44 *	81
77 *	101 *	49 *	105 *
126	153 *	52 *	114 *
169	180 *	70	119
	183 *	74	123
B	194 *	151 *	157
		177	158
118 *		187 *	167
128 *		201 *	168
138 *			189 *
156 *			
170 *			

* Congeners included in Canadian Standard CLB-1. The remaining congeners comprising CLB-1 are Nos. 15, 31, 40, 54, 60, 86, 103, 121, 129, 137, 141, 143, 154, 159, 171, 173, 182, 185, 191, 195, 196, 200, 202, 203, 205, 206, 207, 208, and 209.

tetrachlorobiphenyl, and No. 194, an octachlorobiphenyl. The lower chlorinated PCBs (those having one to four chlorines) are for the most part nontoxic. Many of these mono- through tetrachlorobiphenyls may be taken up readily by organisms but also eliminated rapidly, and thus are not bioaccumulated to a great extent. Most of the highly chlorinated congeners (those having 8 to 10 chlorines) occur only in low concentrations in the environment, and may be relatively unavailable to organisms. The 15 Group 1 and 2 congeners taken together account for as much as 66 percent of total PCB in animal tissues. Congeners 138 and 153, in particular, are major components of technical PCB formulations (Safe et al. 1985), and together account for over 20 percent of total PCB in several of the tissue samples (almost 40 percent in porpoise).

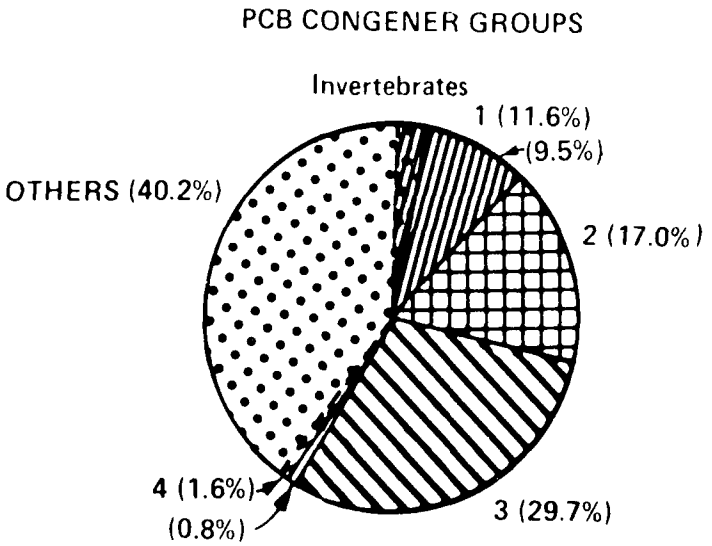
36. Group 3 congeners are of moderate priority in assessing the potential of a PCB-contaminated sediment for adverse biological impact. Congeners

assigned to Group 3 are weak or noninducers, but have numerous reported environmental occurrences or represent at least 10 percent composition of total PCB in tissue samples. Group 3 congeners are most abundant in the fish and invertebrate samples of Table 1, collectively making up 13 to 46 percent of total PCB. Bird and mammal tissues generally have lower Group 3 abundances, from 9 to 19 percent. Group 3 congeners individually represent up to 20 percent of total PCB in tissues. Group 3 spans the isomer groups from tri- through octachlorobiphenyl.

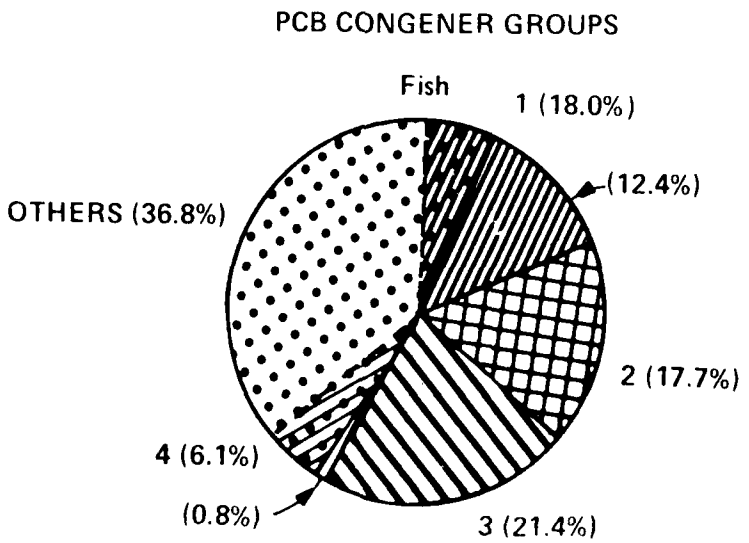
37. Group 4 consists of mixed-type inducers that have few reported environmental occurrences. These congeners generally accumulate in low amounts, if at all, in animal tissues. One Group 4 congener, No. 123, is reported in relatively high amounts in organisms from the Dutch Wadden Sea (Duinker and Hillebrand 1983). However, their chromatographic analyses could not separate this congener from the coeluting congener 149, which is not known to exhibit enzyme-inducing ability. It is likely that the concentration calculated from this mixed peak is due primarily to No. 149 rather than to No. 123. The former is reported in a number of other samples, whereas the latter is not (Table 1). The same situation exists for the Group 1A congener No. 77, which coeluted with No. 110 in the Duinker and Hillebrand analyses. Thus, the high relative abundances shown for No. 77 in seston and plaice (Table 1) are likely attributable to the noninducer No. 110, instead.

38. Group 4 congeners are considered of possible importance because of their potential for toxicity. Congener 105, in particular, is potentially highly toxic (Yamamoto et al. 1976) but contains two adjacent unsubstituted carbons and is rapidly metabolized (Safe 1987). Brown et al. (1984) also found No. 105 to be one of the most rapidly dechlorinated pentachlorobiphenyls in Hudson River sediments. The other Group 4 congeners apparently do not occur frequently in nature and are probably not bioaccumulated to any great extent.

39. The relative proportions of the congener groups in invertebrates, fish, birds, and mammals, based on the data of Table 1, are illustrated in Figure 1. The importance of Groups 1 and 2 increases with trophic level, while the proportions of Group 3 and Others (all congeners not included in any of the four groups) decline. Group 4 remains of relatively little importance in all animal groups, especially when the high relative abundances of the mixed-peak congeners 123/149 (cross-hatched sections) are removed. Groups 1,

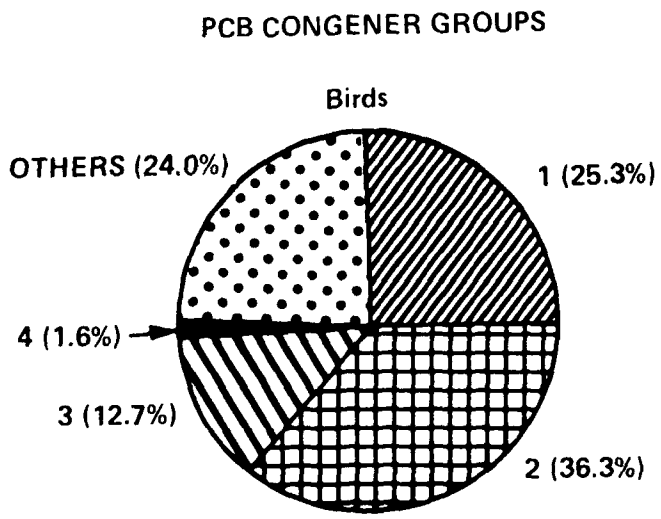


a. Invertebrates

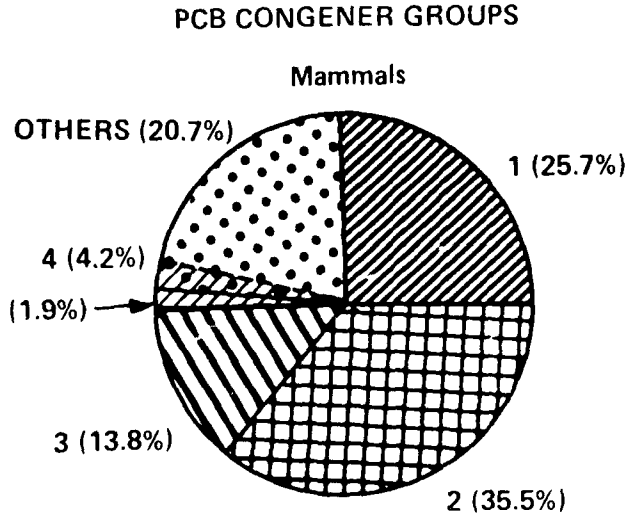


b. Fish

Figure 1. PCB congener groups (Continued)



c. Birds



d. Mammals

Figure 1. (Concluded)

2, and 3 combined make up 58, 57, 74, and 75 percent of total PCB in invertebrates, fish, birds, and mammals, respectively.

Regulatory Evaluation of PCB-Contaminated Dredged Material

40. Disposal options for PCB-contaminated dredged material can be better evaluated by quantitating PCBs as specific congeners rather than as total PCB or as Aroclor equivalents (McFarland, Clarke, and Gibson 1986). Specific congener analysis allows a more accurate assessment of the potential for unacceptable adverse biological effects by focusing only on those congeners that are prevalent in the environment, preferentially bioaccumulated, or potentially toxic. The most important of these are the congeners assigned to Groups 1 and 2. It is recommended that all 15 congeners be included in regulatory evaluations involving PCB-contaminated sediment. However, we recognize that the limitations of analytical laboratories may for the present preclude analysis of Group 1A congeners to the requisite low (parts per trillion) levels for detection in environmental samples. The congeners in Group 3 are important in terms of environmental prevalence and relative abundance in animal tissues, and most of these should be analyzed as well. Group 4 congeners may be of lesser importance in the environment, but are toxicologically active and thus should be analyzed if possible.

41. In Canada, there has recently been developed an analytical standard for PCB congener-specific analysis by capillary column gas chromatography (CLB-1), (Atlantic Research Laboratory, National Research Council, Halifax, Nova Scotia). The Canadian standard mixture contains 51 congeners, including 12 of the 15 congeners composing Groups 1 and 2 (Table 2). Ten of the remaining 21 congeners composing Groups 3 and 4 are also included in the Canadian standard. As yet, the United States has not adopted a selected PCB congener standard mixture, but most of the congeners in the four priority groups of Table 2 are commercially available as pure substances. The relatively high cost of preparing a "standardization cocktail" from individual congeners, as well as quality assurance considerations, suggests that a standard mixture similar to the Canadian CLB-1 should be developed.

42. It is important to emphasize that the specific PCB congeners recommended here for regulatory evaluation of PCB-contaminated sediment constitute guidance based on current knowledge. These recommendations are considered

preliminary for two reasons. First, congener-specific analyses that include a substantial number of PCB congeners are not routinely done, and thus there is not a wealth of data in the literature concerning concentrations of individual congeners in environmental samples. Different patterns of environmental prevalence or relative abundances of congeners in animal tissues may emerge as a result of additional studies. Second, research continuing at the WES and elsewhere* suggests that the toxicity and bioavailability of PCB congeners are exceedingly complex issues. Potential for toxicity, particularly to nonmammalian species, is probably not fully described by classification of PCB congeners according to type of mammalian microsomal enzyme induction. Much additional research is needed to adequately characterize the bioavailability and toxicity of specific congeners or mixtures of congeners to aquatic organisms under controlled laboratory conditions, let alone under the highly variable field conditions encountered during dredging and disposal operations. It is likely that the composition of the priority groups will change somewhat over time as more environmental samples are analyzed for specific congeners, new hypotheses are tested, and research results augment our knowledge of the biological importance of these congeners.

Summary

43. This report presents a preliminary recommendation of specific PCB congeners for use in the regulatory evaluation of dredged material. Thirty-six congeners are considered important based on their potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues. These congeners may be assigned to four priority groups. Group 1 includes the three MC-type MFO inducing congeners, along with five mixed-type inducers that have been reported numerous times in environmental samples and can be fairly abundant in tissues. The seven Group 2 congeners are PB-type inducers that also have numerous reported environmental occurrences and high relative abundances, especially in avian and mammalian

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* Personal Communications, 1987; T. Dillon, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.; N. Rubinstein, US Environmental Protection Agency, Environmental Research Laboratory, Narragansett, R. I.; S. Safe, College of Veterinary Medicine, Texas A&M University, College Station, Tex.

samples. Group 3 congeners are weak or noninducers that occur frequently and in relatively high concentrations, particularly in fish and invertebrate tissues. Groups 1, 2, and 3 combined comprise up to 75 percent of total PCB in animal tissues. Group 4 includes 11 mixed-type inducers that have been reported infrequently in environmental samples and in relatively low amounts. Group 4 congeners, though scarce in environmental matrices, are considered to be of possible concern because of their potential for toxicity.

44. Regulatory evaluation of PCB-contaminated dredged material can be better accomplished by analyzing samples for the specific congeners in the four priority groups than by analyzing for total PCB or Aroclor equivalents. This would permit a more accurate assessment of the potential for unacceptable adverse ecological impact by focusing only on those congeners that are prevalent in the environment, preferentially bioaccumulated, or potentially toxic. This approach would be facilitated by the development of a standard PCB congener mixture for analysis of environmental samples, such as the one in use in Canada.

45. Ongoing research at the WES continues to focus on the ecological importance of PCB congeners. Experiments are planned or currently in progress to develop kinetic models of bioaccumulation, investigate the effects of suspended sediment and other environmental factors on bioavailability, and relate uptake of PCB congeners to reproductive effects in aquatic animals.

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Appendix A: Numbering of PCB Congeners*

No.	Structure
	Monochlorobiphenyls
1	2
2	3
3	4
	Dichlorobiphenyls
4	2,2'
5	2,3
6	2,3'
7	2,4
8	2,4'
9	2,5
10	2,6
11	3,3'
12	3,4
13	3,4'
14	3,5
15	4,4'
	Trichlorobiphenyls
16	2,2',3
17	2,2',4
18	2,2',5
19	2,2',6
20	2,3,3'
21	2,3,4
22	2,3,4'
23	2,3,5
24	2,3,6
25	2,3',4
26	2,3',5
27	2,3',6
28	2,4,4'
29	2,4,5
30	2,4,6
31	2,4',5
32	2,4',6
33	2',3,4
34	2',3,5
35	3,3',4
36	3,3',5
37	3,4,4'
38	3,4,5
39	3,4',5
	Tetrachlorobiphenyls
40	2,2',3,3'
41	2,2',3,4
42	2,2',3,4'
43	2,2',3,5
44	2,2',3,5'
45	2,2',3,6
46	2,2',3,6'
47	2,2',4,4'
48	2,2',4,5
49	2,2',4,5'
50	2,2',4,6
51	2,2',4,6'

No.	Structure
	Tetrachlorobiphenyls
52	2,2',5,5'
53	2,2',5,6'
54	2,2',6,6'
55	2,3,3',4
56	2,3,3',4'
57	2,3,3',5
58	2,3,3',5'
59	2,3,3',6
60	2,3,4,4'
61	2,3,4,5
62	2,3,4,6
63	2,3,4',5
64	2,3,4',6
65	2,3,5,6,
66	2,3',4,4'
67	2,3',4,5
68	2,3',4,5'
69	2,3',4,6
70	2,3',4',5
71	2,3',4',6
72	2,3',5,5'
73	2,3',5',6
74	2,4,4',5
75	2,4,4',6
76	2',3,4,5
77	3,3',4,4'
78	3,3',4,5
79	3,3',4,5'
80	3,3',5,5'
81	3,4,4',5
	Pentachlorobiphenyls
82	2,2',3,3',4
83	2,2',3,3',5
84	2,2',3,3',6
85	2,2',3,4,4'
86	2,2',3,4,5
87	2,2',3,4,5'
88	2,2',3,4,6
89	2,2',3,4,6'
90	2,2',3,4',5
91	2,2',3,4',6
92	2,2',3,5,5'
93	2,2',3,5,6
94	2,2',3,5,6'
95	2,2',3,5',6
96	2,2',3,6,6'
97	2,2',3',4,5
98	2,2',3',4,6
99	2,2',4,4',5
100	2,2',4,4',6
101	2,2',4,5,5'
102	2,2',4,5,6'
103	2,2',4,5',6
104	2,2',4,6,6'

No.	Structure
	Pentachlorobiphenyls
105	2,3,3',4,4'
106	2,3,3',4,5
107	2,3,3',4',5
108	2,3,3',4'5'
109	2,3,3',4,6
110	2,3,3',4',6
111	2,3,3',5,5'
112	2,3,3',5,6
113	2,3,3',5',6
114	2,3,4,4',5
115	2,3,4,4',6
116	2,3,4,5,6
117	2,3,4',5,6
118	2,3',4,4',5
119	2,3',4,4',6
120	2,3',4,5,5'
121	2,3',4,5',6
122	2',3,3',4,5
123	2',3,4,4',5
124	2',3,4,5,5'
125	2',3,4,5,6'
126	3,3',4,4',5
127	3,3',4,5,5'
	Hexachlorobiphenyls
128	2,2',3,3',4,4'
129	2,2',3,3',4,5
130	2,2',3,3',4,5'
131	2,2',3,3',4,6
132	2,2',3,3',4,6'
133	2,2',3,3',5,5'
134	2,2',3,3',5,6
135	2,2',3,3',5,6'
136	2,2',3,3',6,6'
137	2,2',3,4,4',5
138	2,2',3,4,4',5'
139	2,2',3,4,4',6
140	2,2',3,4,4',6'
141	2,2'3,4,5,5'
142	2,2',3,4,5,6
143	2,2',3,4,5,6'
144	2,2',3,4,5',6
145	2,2',3,4,6,6'
146	2,2',3,4',5,5'
147	2,2',3,4',5,6
148	2,2',3,4',5,6'
149	2,2',3,4',5',6
150	2,2',3,4',6,6'
151	2,2',3,5,5',6
152	2,2',3,5,6,6'
153	2,2',4,4',5,5'
154	2,2',4,4',5,6'
155	2,2',4,4',6,6'
156	2,3,3',4,4',5
157	2,3,3',4,4',5'
158	2,3,3',4,4'6
159	2,3,3',4,5,5'
160	2,3,3',4,5,6

No.	Structure
	Hexachlorobiphenyls
161	2,3,3',4,5',6
162	2,3,3',4',5,5'
163	2,3,3',4',5,6
164	2,3,3',4',5',6
165	2,3,3',5,5',6
166	2,3,4,4',5,6
167	2,3',4,4',5,5'
168	2,3',4,4',5',6
169	3,3',4,4',5,5'
	Heptachlorobiphenyls
170	2,2',3,3',4,4',5
171	2,2',3,3',4,4',6
172	2,2',3,3',4,5,5'
173	2,2',3,3',4,5,6
174	2,2',3,3',4,5,6'
175	2,2',3,3',4,5',6
176	2,2',3,3',4,6,6'
177	2,2',3,3',4',5,6
178	2,2',3,3',5,5',6
179	2,2',3,3',5,6,6'
180	2,2',3,4,4',5,5'
181	2,2',3,4,4',5,6
182	2,2',3,4,4',5,6'
183	2,2',3,4,4',5',6
184	2,2',3,4,4',6,6'
185	2,2',3,4,5,5',6
186	2,2',3,4,5,6,6'
187	2,2',3,4',5,5',6
188	2,2',3,4',5,6,6'
189	2,3,3',4,4',5,5'
190	2,3,3',4,4',5,6
191	2,3,3',4,4',5',6
192	2,3,3',4,5,5',6
193	2,3,3',4',5,5',6
	Octachlorobiphenyls
194	2,2',3,3',4,4',5,5'
195	2,2',3,3',4,4',5,6
196	2,2',3,3',4,4',5,6'
197	2,2',3,3',4,4',6,6'
198	2,2',3,3',4,5,5',6
199	2,2',3,3',4,5,6,6'
200	2,2',3,3',4,5',6,6'
201	2,2',3,3',4,5',5,6'
202	2,2',3,3',5,5',6,6'
203	2,2',3,4,4',5,5',6
204	2,2',3,4,4',5,6,6'
205	2,3,3',4,4',5,5',6
	Nonachlorobiphenyls
206	2,2',3,3',4,4',5,5',6
207	2,2',3,3',4,4',5,6,6'
208	2,2',3,3',4,5,5',6,6'
	Decachlorobiphenyl
209	2,2',3,3',4,4',5,5',6,6'

* Adopted from Ballschmiter and Zell (1980).